

**PROGRAM NARRATIVE STUDY PLAN
FOR MAMMALS RESEARCH
FY 2016-17**

State of:	<u>Colorado</u>	:	<u>Parks and Wildlife</u>
Cost Center:	<u>3430</u>	:	<u>Mammals Research</u>
Work Package:	<u>3004</u>	:	<u></u>
Task No.	<u>2</u>	:	<u></u>
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Federal Aid			
Project No.	<u>W-245-R, Segment 2</u>		

Spatio-Temporal Dispersal Patterns of Mountain Goats: an evaluation of mountain goat harvest management as a tool to benefit bighorn sheep

Principal Investigator

Eric J. Bergman, Mammals Researcher, Colorado Parks and Wildlife

Cooperators

Julie Mao, Terrestrial Wildlife Biologist, Colorado Parks and Wildlife
Field Operations Staff, Area 8, Colorado Parks and Wildlife

STUDY PLAN APPROVAL

Prepared by:	<u>Eric J. Bergman</u>	Date:	<u>25 April 2017</u>
Submitted by:	<u>Eric J. Bergman</u>	Date:	<u>25 May 2017</u>
Reviewed by:	<u>Andy Holland</u>	Date:	<u>27 April 2017</u>
	<u>Adam Behney</u>	Date:	<u>15 May 2017</u>
Biometrician:	<u>Jon Runge</u>	Date:	<u>22 May 2017</u>
Approved by:	<u>Chuck Anderson</u>	Date:	<u>22 May 2017</u>
	Mammals Research Leader		

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A Study Plan Proposal Submitted by:

Eric J. Bergman, Mammals Researcher, Colorado Parks and Wildlife

A. NEED

Due to their iconic status, Rocky Mountain bighorn sheep (*Ovis Canadensis*) are a high profile species in Colorado. This status stems from many sources, including the fact that bighorn sheep are Colorado's state animal and they embody the spirit of Colorado's wilderness, they are native to Colorado, well suited to Colorado's alpine terrain, are highly valued as a watchable wildlife species, and hunting opportunities are extremely limited and coveted. More than any other combination of two large mammal species, the interactions between bighorn sheep and mountain goats (*Oreamnos americanus*) play a central role in the management of these species. Prior to the 1940s, mountain goats did not exist in Colorado. Following a 1948 transplant into the Collegiate Peaks mountain range and several subsequent transplants and translocations, mountain goat herds are now fixtures in many parts of Colorado (George et al. 2009). The continued presence of mountain goats in Colorado is a testament to the resilience and ability of this species to survive, but also a reflection on the suitability of Colorado's alpine habitat. In 1993, the Colorado Wildlife Commission gave mountain goats native species status (George et al. 2009). Since then, management objectives for mountain goats are focused on meeting two goals, which at times, can be in conflict. Due to the iconic status and lower resilience of bighorn sheep, a fundamental goal of mountain goat management is to limit growth, encroachment, or displacement of high priority (i.e., Tier I and II) bighorn sheep herds. Outside of areas designated as high priority for bighorn sheep, the goal for mountain goat management focuses on maintaining viable and productive herds.

Colorado's Bighorn Sheep Management Plan (George et al. 2009) most succinctly addresses the topic of mountain goat and bighorn sheep interactions in Colorado. The topic of competition between these species as well as the ecological impacts of non-native mountain goats have also been highlighted in other jurisdictions such as Yellowstone National Park (Lemke 2004, Flesch et. al. 2016), southern Montana (Lemke 2004), and Olympic National Park (Scheffer 1993). In spite of the frequency that competition between these two mountain ungulates is discussed in the scientific literature and in herd management plans, studies that simultaneously monitored both species are infrequent. Yet research from Colorado makes it clear that dietary overlap (Dailey et al. 1984) and competitive displacement (Reed 2001) both occur. However, the conclusions about the population level impacts of this competition remain elusive. Anecdotally, appearance of mountain goats has coincided with declines in bighorn sheep in several parts of Colorado (A. Holland, CPW, personal communication).

Moving beyond the management complexities that stem from the overlap of bighorn sheep and mountain goats in Colorado, Colorado's Bighorn Sheep management plan also provides a foundational perspective for mountain goat research (George et al. 2009). For instance, this plan calls for the development of inventory and management protocols for mountain goats, as well as research focused on the survival, recruitment and density of mountain goat populations (George et al. 2009). The Bighorn Sheep Management Plan also identifies

strategies that rely on the use of controlled experiments to test the efficacy of census and removal methods, and to determine whether hunting is a source of additive mountain goat mortality (George et al. 2009). Despite the suite of research questions that warrant attention, the most utilitarian approach for addressing these questions hinges on opportunities that can be coupled with changes in harvest management decisions.

Current management of mountain goats, primarily via harvest, occurs in Colorado's 17 mountain goat specific Game Management Units (GMUs). However, dispersal and range expansion into and observations of mountain goats in other parts of Colorado's alpine habitat are common. Dispersal and range expansion represent both a dilemma and an opportunity for Colorado Parks and Wildlife (CPW). Dispersal and range expansion are often interpreted as indicators that mountain goats continue to thrive in Colorado. However, perceived displacement of bighorn sheep by mountain goats is a concern. Even beyond Colorado, proliferation, dispersal, and expansion of mountain goat range into that of native bighorn sheep is often an undesired consequence of mountain goat introductions (Flesch et al. 2016).

During the past 2 decades, the mountain goat herd comprising management unit G12 experienced dramatic increases in abundance (Figs. 1 and 2). Based on observations by local biologists and District Wildlife Managers, and also from bighorn sheep hunters, mountain goats first appeared in G12 during the mid-1980s. Those founding individuals for the G12 herd likely dispersed from neighboring mountain ranges such as the Collegiate Peaks, the Sawatch Range, and the Ragged Mountains. Starting in the early 2000s, CPW initiated a more concerted effort to monitor and catalog the total number of mountain goats in G12. Between 2004 and 2016, the herd grew from an estimated 75 animals to approximately 300 animals (Fig. 2).

Mountain goat unit G12 overlaps a single Rocky Mountain bighorn sheep data analysis unit (RBS13, Fig. 1). Within RBS13, harvest management of bighorn sheep occurs within two GMUs (S13 and S25). The highest concentration of mountain goats in G12 currently overlaps with bighorn sheep GMU S13 in the eastern half of the study area, although mountain goats are also found at lower densities in areas overlapping GMU S25.

Abundance estimates for bighorn sheep in S13 during the late 1980s and early 1990s approximated 150–250 animals (Fig. 2). At that time, mountain goats likely were at a low population density across the landscape. However, domestic sheep grazing occurred in the Willow Creek and Snowmass Creek areas until the 1980s; thus, the potential for competition and disease interactions between bighorn sheep and domestic sheep existed. From the mid-1990s to present, the bighorn sheep herd declined by one-third to one-half of its earlier size; specifically, the herd segment that once occupied Willow and Snowmass creeks disappeared. Whether the decline was a result of a disease outbreak is unknown (G. Byrne, CPW (retired), personal communication), but it also coincided with the expansion of mountain goats. The role that domestic sheep or mountain goats played in the decline of bighorn sheep cannot be discerned after-the-fact, but future management of mountain goats to help enhance bighorn sheep has been identified as a CPW management objective.

In addition to questions about bighorn sheep and harvest management, many additional questions surround the role and function of mountain goats in Colorado. As noted, while formally recognized as a native species, the current existence of mountain goats in Colorado is due to translocation efforts that date to the 1940s, 1950s, and 1960s. From a land management perspective, much of Colorado's alpine and suitable mountain goat and bighorn sheep habitat occurs within United States Forest Service (USFS) wilderness areas. While the intent, esthetic, and spirit of wilderness areas are not violated by introduced species, these wilderness values

could be enhanced by fostering populations of native, extant species such as bighorn sheep. Another attribute of Colorado's alpine habitat is its appeal to people for recreational purposes. Mountaineers, skiers, climbers, hunters, anglers, and backpackers flock to Colorado's mountainous terrain during all times of the year. More so than any other mountain ungulate, mountain goats exploit this human presence by looking to human waste (i.e., urine and the salt that it provides) as an important source of nutrients. Anecdotally, mountain goats are known to seek out alpine areas intensively used by people (Gottlieb 2011, Landers 2016), yet no formal quantification of this behavior has occurred. This mountain goat behavior and the subsequent human-wildlife interactions that result are a growing concern in Colorado as human safety is a concern for wildlife and land management agencies alike (Gottlieb 2011, Landers 2016). Finally, a potential ancillary benefit of mountain goat research that also stems from human-wildlife interactions in remote alpine settings is linked to opportunities for citizen-scientist based data collection in wildlife management (Boyce and Corrigan 2017, Flesch and Belt 2017). Observations of wildlife species can be of great value to wildlife biologists, especially those observations that are: 1) associated with accurate spatial and temporal stamps, 2) those occurring in remote or Wilderness settings, and 3) those of species that typically receive nominal monitoring investments.

B. OBJECTIVES

Primary Objectives

- 1) To quantify transition rates (including dispersal, movement, and range expansion) of mountain goats among neighboring ridgetops and suitable habitat segments.
- 2) To determine the extent of spatial overlap between mountain goats and bighorn sheep.
- 3) To investigate dual species management strategies for native bighorn sheep that complement Wilderness land management strategies

Secondary Objectives

While not intended to be explicitly evaluated as part of this study, our data will provide cursory information pertaining to movement of mountain goats in relation to human recreational use of alpine areas. Our data will also allow us to explore opportunities to develop citizen science-based population monitoring of mountain goats and bighorn sheep in USFS wilderness settings.

C. EXPECTED RESULTS OR BENEFITS

Much of the complexity surrounding the simultaneous management of mountain goats and bighorn sheep in Colorado stems from the lack of information concerning dispersal, movement rates, and range expansion of each species. This research will directly quantify the rates of these behaviors of mountain goats among neighboring ridgetops and areas of suitable mountain goat habitat, which in turn will directly feed into harvest management strategies for the species. It is assumed that hunter harvest of mountain goats is an effective tool for lowering mountain goat densities in localized areas. If the probability of immediate dispersal into and

recolonization of those intensive harvest areas by mountain goats is low, then the utility of mountain goat harvest as a tool to minimize overlap with bighorn sheep will be viewed as an effective tool at small spatial scales. In this scenario, wildlife biologists and managers could confidently apply high intensity mountain goat harvest regimes, in localized areas, with the confidence that mountain goats would not quickly repopulate those areas within one year. If the probability of immediate dispersal into and recolonization of intensive harvest areas by mountain goats is high, then the use of harvest of mountain goats as a management tool for native bighorn sheep will likely be most useful at broader spatial and temporal scales. Under this latter scenario, wildlife biologists and managers would be better served by applying high mountain goat harvest pressure at the GMU level and over longer periods of time.

D. APPROACH

Dispersal Model Development

Assessment of animal movement can take many forms. Whereas many movement models focus on quantifying rates of movement or modeling habitat variables that influence the location of movement paths, the purpose of this research is to determine the probability that mountain goats will move between segments of suitable range. Multi-state models can be structured to estimate the probability that an animal will move from one “state” (i.e., a river drainage or mountain top) to a neighboring “state”. For the purposes of this research, a “state” within the multi-state framework should be viewed as a delineated segment of mountain goat range within G12. From a technical standpoint, observation of a marked animal outside of its original capture segment is a product of the probabilities of that animal: 1) surviving from the time of marking to the time of observation, 2) moving to a new segment, and 3) observation of that animal in the new segment. Estimating each of these three probabilities requires many data points, yet it is the second probability (i.e., the probability of an animal moving to a new segment) that is of primary interest in this study. Fortunately, modern technology allows for the simplification of multi-state models in several ways. First, modern “survival” collars notify researchers when a collared animal has died. Similarly, these collars utilize satellite technology and repeatedly provide new locations for collared animals. A characteristic of having frequent locations is that the resighting probability is largely invariant and can be assumed to be 1 (i.e., researchers always know where an animal is located). Thus, by not allowing resighting probabilities to vary, the only unknown parameters become survival and the probabilities that an animal transitions from one segment to another (Fig. 3). Accordingly, the necessary sample size of marked animals is reduced and meaningful conclusions can be drawn from a smaller sample of animals.

Sample Size Calculation

The objective of this research is to determine the probability that mountain goats will disperse from one segment of suitable habitat to a neighboring segment of suitable habitat in G12. Most management decisions and particularly those related to harvest of ungulates are made on an annual basis. Thus, mountain goat transitions from one segment to another are most relevant if they are considered over a 1-year cycle. Thus, we are interested in quantifying dispersal rates of those animals that leave one segment and remain in a new segment for a year or

longer. Documenting short-term forays into neighboring segments will be an ancillary benefit of data collected from this study.

Sample size calculations for this research are based on binomial probabilities. The probability that a mountain goat transitions from one segment of suitable habitat to another can vary between 0–1. In the absence of preliminary or pilot dispersal data, we assumed that a 50% probability of an individual mountain goat dispersing would be meaningful to bighorn sheep management. More succinctly, transition rates less than 50% would be indicative that mountain goats are less likely to repopulate low-density segments within 1 year. As transition probabilities increase, the ability to detect an individual transition event increases with a given number of radio collars. However, higher transition rates are also indicative that mountain goats quickly find and repopulate low-density habitat segments. This latter scenario would provide evidence that CPW should consider mountain goat harvest at broader spatial and temporal scales when put in the context of bighorn sheep management goals.

Based on these biological sideboards, and recognizing management objectives, our goal is to have a coefficient of variation less than 0.20 for detecting mountain goat transition if the individual probability of transitioning is $\geq 50\%$. Based on these criteria, a minimum sample of 30 mountain goats equipped with “survival” satellite collars is required (Fig. 4).

Mountain Goat Harvest

As discussed, the historical presence of bighorn sheep and mountain goats in RBS13 is well documented. Abundance of bighorn sheep in RBS 13 declined by an estimated 67% from 1986–2016 (Fig. 2). Between the mid-1980s and 2016, the abundance of mountain goats in this area (G12) increased from just a few animals to ~300 (Fig. 2). A mountain goat hunting season in G12 was opened in 1995 with a quota of 6 licenses, and from 1995–2008, the quota remained between 5–8 animals (Fig. 5). Despite successful harvest, the abundance of mountain goats in G12 increased from 1995–2008. In response to the growing population, CPW conservatively increased the hunting license quota over the next decade, up to 30 licensed in 2016 (Fig. 5). Despite this upward trend in license allocation, mountain goat abundance in G12 also increased. In response, during 2017, CPW will implement a more pronounced increase in the number of mountain goat hunting licenses ($n = 60$). This proposed increase in mountain goat harvest will serve as the treatment in a harvest management study. The increase in mountain goat harvest will likely occur in small intensive harvest management areas (i.e., areas where a disproportionate amount of harvest occurs, as delineated by clusters of harvest locations from past mountain goat hunters in G12). Subsequently, mountain goat density in these localized intensive management segments is expected to drop, allowing researchers to quantify dispersal and recolonization rates as mountain goats from neighboring segments repopulate those areas.

Field Methods

Following the conceptual model for dispersal, we will quantify mountain goat movement rates using “survival” satellite GPS collars. These collars provide researchers, biologists, and managers with daily GPS locations (locations as often as every 12 hours) via satellite communication links. These collars also provide immediate notification of mortality events. Thus, as discussed, these collars provide a cost-effective mechanism for assessing transition probabilities within a multi-state framework. Following the 2017 hunting seasons, 30

mountain goats will be captured and fitted with satellite neck collars. Whereas dietary overlap and exploitative competition likely occurs between bighorn sheep and mountain goats in S13 and G12, this study is focused on interference competition and the potential for displacement of bighorn sheep by mountain goats. From this perspective, the distribution of collars among male and female mountain goats is of nominal importance as either sex is capable of displacing bighorn sheep. However, due to hunter selection, adult male mountain goats have a higher harvest probability during hunting seasons. To balance our desire to sample a representative subset of animals (i.e., both adult male and adult females) with the desire to maximize the longevity that each sampled animal remains alive and in the study, we will strive to capture 10 adult male and 20 adult female mountain goats. The majority of mountain goats in G12 are located in the Maroon Bells - Snowmass Wilderness Area. All Wilderness captures will be closely coordinated with USFS personnel, and only following the necessary Minimum Requirements Analysis (MRA).

For this study, mountain goats will be captured using 3 techniques: ground darting, helicopter darting, and helicopter net-gunning. For captures involving chemical immobilization via darting, mountain goats will be sedated using 1 of 3 potential drugs: etorphine (0.5cc, 10 mg/ml), carfentanil (0.5cc, 4 mg/ml), or thiafentanil (0.5cc, 10 mg/ml).

Ground darting has the potential to be the least efficient capture method. However, due to the lack of helicopter pursuit, disturbance levels will also be lower. For ground darting, capture crews will visit sites where mountain goats are commonly observed such as backcountry campsites, hiking trails, or mountaintops. Once at these sites, temporary (3–5 day) bait sites will be created by deploying granular, naturally colored salt in weighted tubs ($\sim 0.13 \text{ m}^2$). When correctly deployed, weighted tubs will provide a visual cue for bait, and salt will be quickly utilized by mountain goats, yet its presence on the landscape will be short-lived (< 5 days), thereby minimizing the temporal impact to any specific area (L. Wolfe, CPW, personal communication). Once mountain goats have recognized a bait site, capture crews will dart individual animals by taking advantage of naturally occurring blinds and topographical features. For ground-based captures, mountain goats will quickly be radio-collared and blood samples will be collected prior to reversing capture drugs. Blood parameters can be used to opportunistically assess animal condition via thyroid hormones, and to assess adaptation to living at abnormally high elevations via red blood cell concentration and blood gas analysis. Handling time will be held to < 5 minutes. No more than 5 mountain goats will be captured at any single site.

The second method, helicopter darting, has the potential to be the most efficient capture method, although disturbance levels will be higher. Helicopter darting will rely on a capture crew comprised of a pilot and a gunner. Upon location, a group of mountain goats will be pursued into suitable and safe darting terrain. A single adult animal will be isolated and pursued until a dart can successfully be placed in the animal. Due to rugged and dangerous terrain, helicopter pursuits will not push mountain goats at full running speed, nor will pursuits exceed 10 minutes. During aerial darting capture efforts, mountain goats will quickly be radio-collared and capture drugs will be immediately reversed. Handling time will be held to < 5 minutes.

In ideal capture locations (i.e., grassy, alpine basins), helicopter net-gunning will also be used to capture mountain goats. Due to concerns over animal safety, helicopter net-gunning can only be used in locations where there is negligible opportunity for mountain goats to fall off cliffs or other precipitous terrain features. However, due to interactions of capture drugs and high altitude, physiological stress to mountain goats can potentially be mitigated by avoiding chemical immobilization when safely feasible. During helicopter net-gunning scenarios,

helicopter pursuit times will not exceed 10 minutes. Once netted, mountain goats will be blind-folded, hobbled, and horns will be covered with short segments of garden hose. Once safely removed from the net, mountain goats will be collared, blood samples will be collected, and animals will be released. Including extraction from net, handling time for mountain goats captured via net-gunning will be held to <10 minutes

At the time of capture, all mountain goats will be assigned to one of 6 pre-identified range segments (Fig. 6). Range segments were delineated by partitioning G12 by river and creek drainages such that a mountain goat on one mountain ridge top would have to cross a drainage or mountain pass to enter a new segment. While the total area of each pre-identified segment varies, the amount of mountain goat habitat within each segment is similar. Subsequent locations of study animals, provided via GPS and satellite communication can be used to quantify dispersal rates (i.e., transition probabilities) of mountain goats between habitat segments.

All collars deployed on mountain goats will be marked with visible, unique identifiers comprised primarily of color-coding and letter or number combinations. These unique identifiers will facilitate visual identification of individual animals in the absence of radio-telemetry. Within a capture-mark-resight framework, unique identifiers allow for more precise abundance estimation (Bowden and Kufeld 1995). As opportunity and public interest develops, spatio-temporal locations of individually marked mountain goats, as well as information about the groups of mountain goats with which they are associated, may provide opportunities to develop novel approaches to monitoring mountain goat herds in remote or Wilderness settings (Boyce and Corrigan 2017).

E. Location

This research will occur in mountain goat unit G12. Specifically, this research will be centered on alpine habitat in the Elk Mountains and include animals from the areas of: Avalanche Creek, Capitol Creek, Snowmass Creeks, Willow Creek, Maroon Creek, Conundrum Creek (all within G12), but also in the area of White Rock Mountain (outside of a current mountain goat GMU).

F. Schedule of Work

Activity	Date
Complete Study Plan and ACUC Approval Process	Apr. 2017–Jun. 2017
Purchase Radio Collars and Address Capture Logistics	July 2017–Nov. 2017
Mountain Goat Hunting Seasons	Sept. 2017–Oct. 2017
Mountain Goat Capture	Winter 2017–2018
Space-Use & Dispersal Monitoring	2018–2020

G. Estimated Costs

Fiscal Year	Category			
	Personnel		Operating	
FY17–18	Bergman	0.10	Federal Aid	\$17,180
	Mao	0.10	External Grants	\$36,970
	DWMs	0.01		
FY18–19	Bergman	0.10	Federal Aid	\$5,850
	Mao	0.10	External Grants	\$0
	DWMs	0.01		
FY19–20	Bergman	0.10	Federal Aid	\$5,850
	Mao	0.10	External Grants	\$0
	DWMs	0.01		

H. Related Federal Aid Projects

Our research will be conducted on federal (i.e., BLM, USFS) and state lands. This study does involve formal collaboration with federal agencies, but it does not duplicate the work of any ongoing federal projects.

I. Literature Cited

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J. Tables and Figures

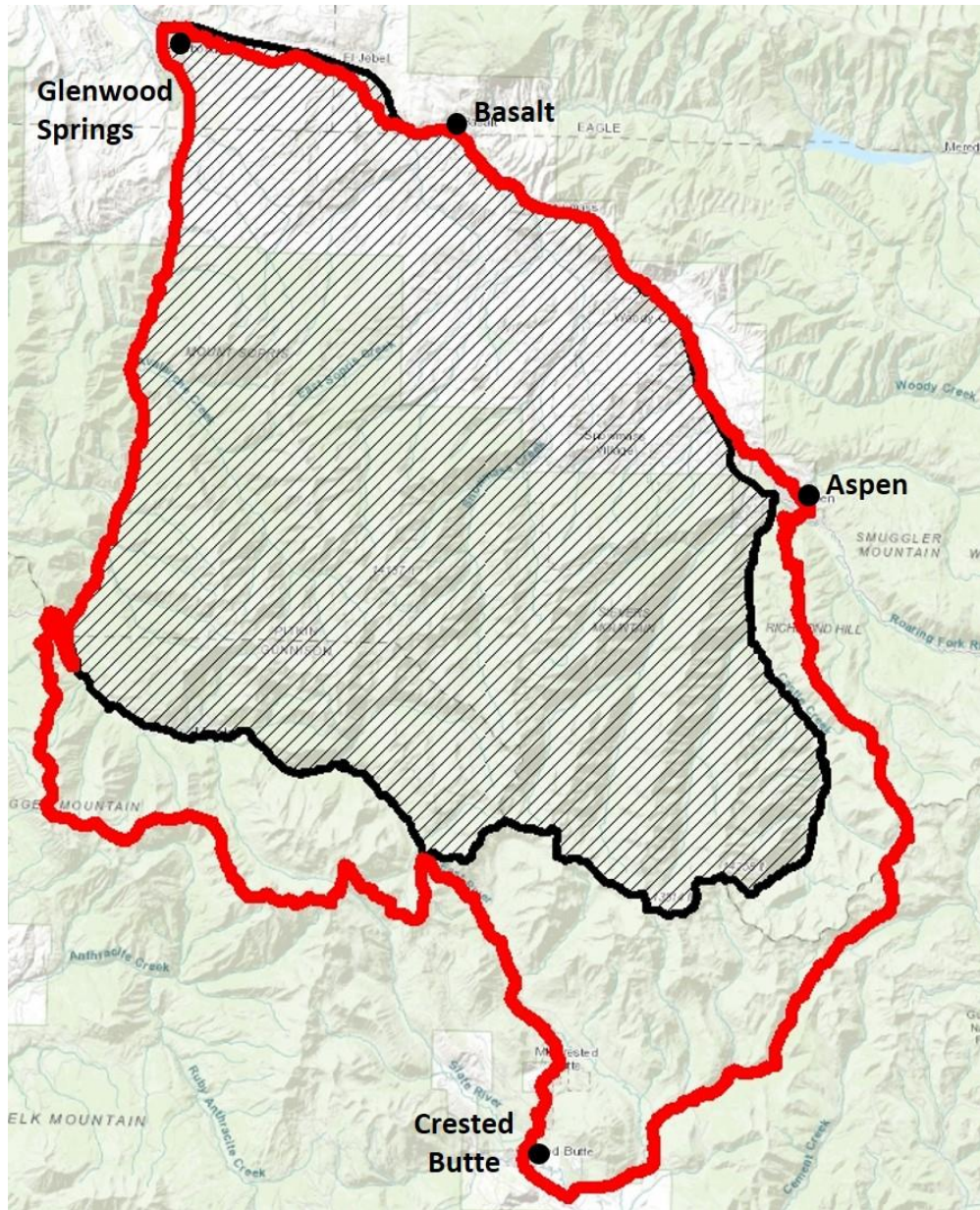


Figure 1. Data Analysis Unit (DAU) boundaries for Rocky Mountain bighorn sheep (RBS13, solid red line) and mountain goat (G12, solid black line with black diagonal cross-fill) in relation to the surrounding communities of Glenwood Springs, Basalt, Aspen, and Crested Butte, Colorado.

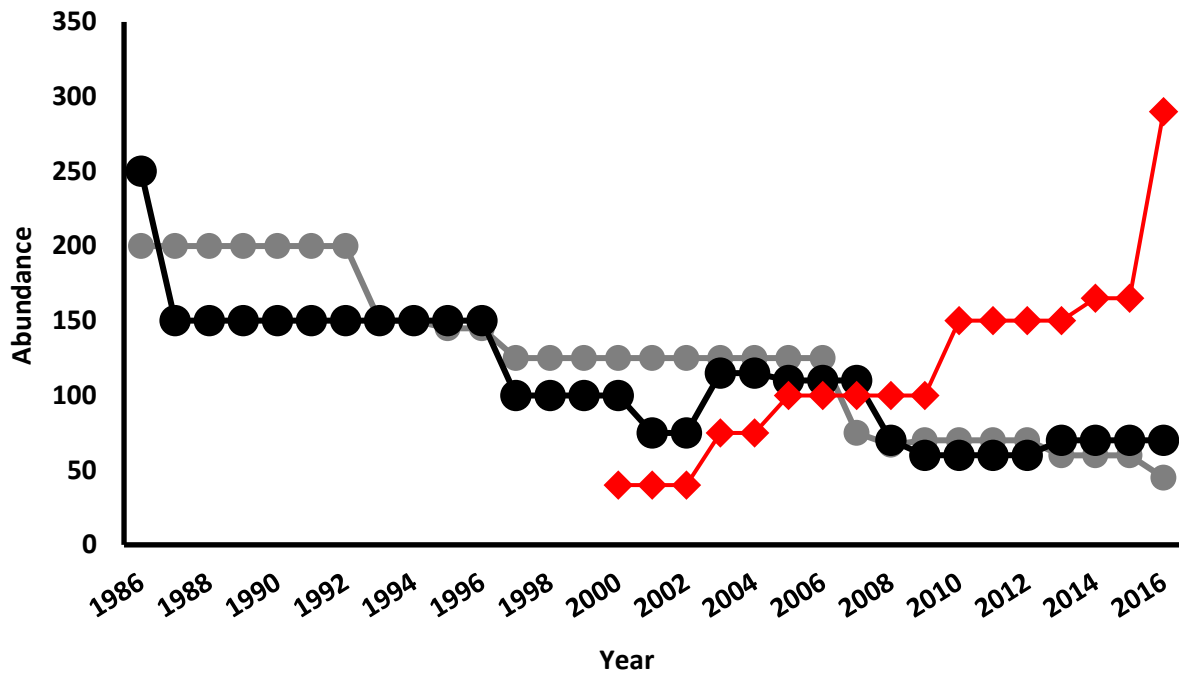


Figure 2. Abundance estimates for Rocky Mountain bighorn sheep and mountain goats in the Glenwood Springs, Basalt, Aspen, and Crested Butte areas of Colorado. The solid black line and black circles reflect bighorn sheep GMU S13, and solid gray lines and gray circles reflect bighorn sheep GMU S25. Mountain goat abundance estimates, depicted by the solid red line and red diamonds, are for mountain goat GMU G12.

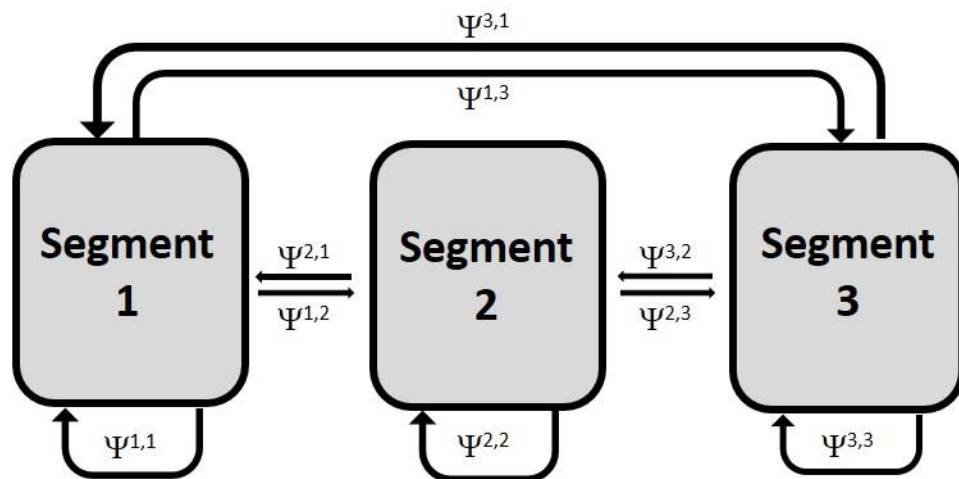


Figure 3. A conceptual multi-state model design to be used for quantify mountain goat dispersal between segments of suitable habitat. In this model, survival and resighting probabilities are invariant and fixed at 1.0, allowing all data to be used to estimate the transition probability (Ψ) between segments. This conceptual model can easily be expanded to include more than 3 segments.

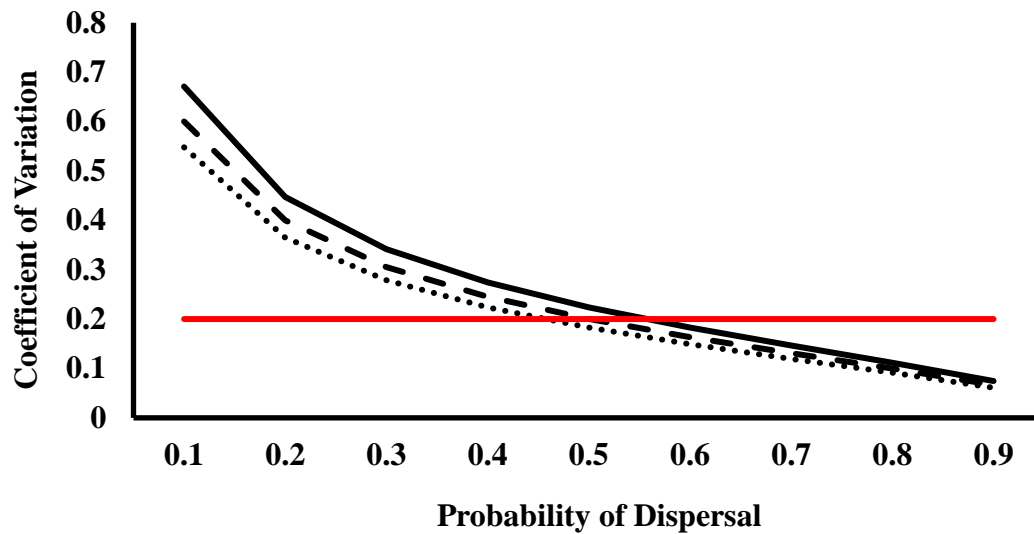


Figure 4. Coefficient of variation of sample size estimates, based on binomial probabilities, of detecting mountain goat dispersal from one segment of suitable habitat to another. Coefficient of variation for samples of 20 (solid black line), 25 (black dashed line), and 30 (black dotted line) mountain goats are shown. For this research, a sample size objective is to have a coefficient of variation ≤ 0.20 (solid red line) of detecting dispersal probabilities > 0.50 . Ultimately, a minimum of 30 collars are required to meet this objective.

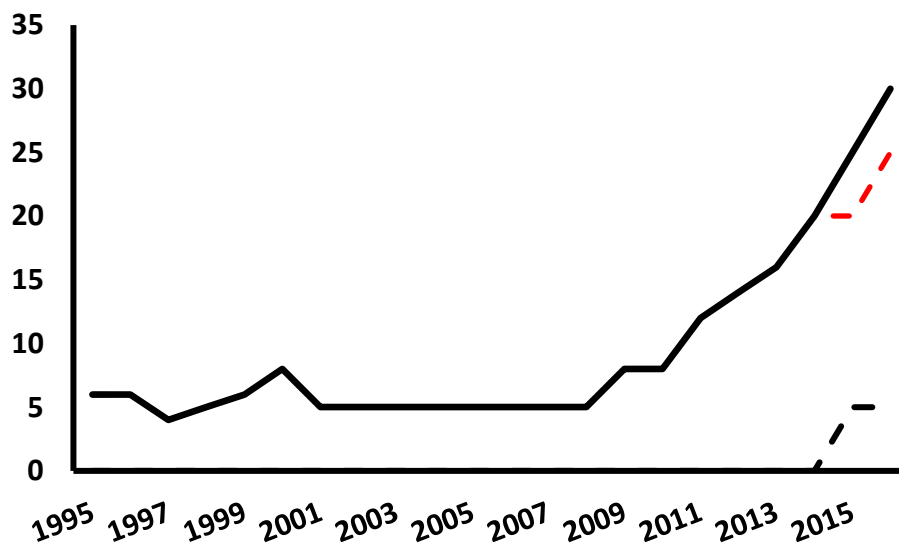


Figure 5. Annual allocation of mountain goat hunting licenses in Data Analysis Unit (DAU) G12. The solid black line depicts all mountain goat licenses, the dashed black line depicts nanny only licenses, and the dashed red line depicts the total number of licenses. Prior to 2015, all mountain goat licenses in G12 were either sex.

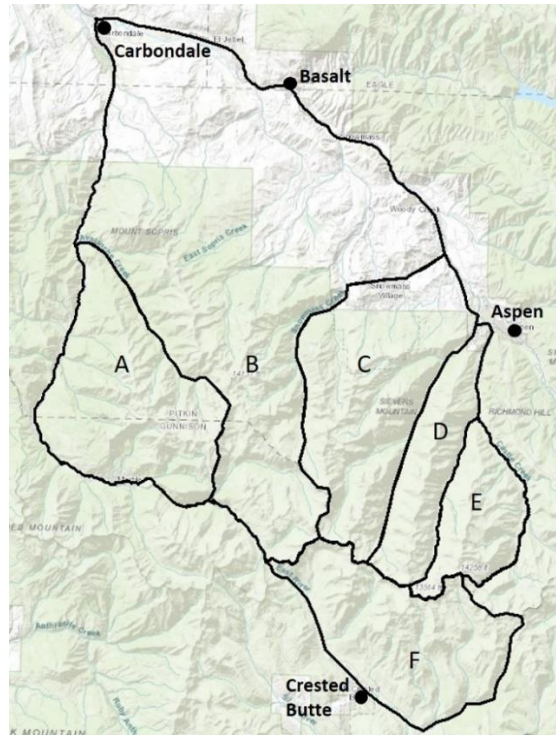


Figure 6. Pre-identified mountain goat habitat segments within Data Analysis Unit (DAU) G12. Locations of mountain goats provided by satellite collars, when mapped according to these habitat segments, allow quantification of dispersal rates using multi-state models.